INITIAL CHEMICAL ENRICHMENT IN GALAXIES

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We present evidence that damped Lyα galaxies detected in spectra of quasars may not have started forming stars until the redshift $z \sim 3$. If damped Lyα absorbers are the progenitors of disk galaxies, then the above result may indicate that star formation in galactic disks first began at $z \sim 3$.

1 Introduction

One definition of the epoch of galaxy formation is when galaxies first began to form stars. Different types of galaxies (e.g., ellipticals and spirals) or different parts of the same type of galaxies (e.g., bulge and disk of spirals) may have formed at different epochs. A important goal of observational cosmology is to identify these different formation epochs.

Conventional wisdom suggests that ellipticals and the spheroidal component of spirals formed very early, followed by disks. The population of galaxies at $z > 3$ identified using the Lyman limit drop-out technique may very well be the progenitors of the spheroidal component of massive galaxies [1,2]. Here we discuss evidence for a sharp rise in the metallicity distribution of damped Lyα absorbers at $z \leq 3$, which may signify the onset of star formation in galactic disks.

2 Results

Damped Lyα (DLA) absorption systems seen in spectra of background quasars are widely accepted to be the progenitors of present-day galaxies [3], although their exact nature (dwarfs, spheroids, or disks?) is still unclear. A program is carried out using the Keck telescopes to study the chemical compositions of the absorbing gas in DLA systems. One of the goals is to (hopefully) identify the epoch of the first episode of star formation in these galaxies, hence constraining theories of galaxy formation.

Figure 1 shows the distribution of [Fe/H] in DLA systems as a function of redshift. Detailed descriptions of the data and analyses are given in refs [4,5]. The low metallicities of DLAs testify the youth of these galaxies: they have yet to make the bulk of their stars. Remarkably, all 6 of the highest redshift absorbers have [Fe/H]≤ -2; while many absorbers have reached ten times

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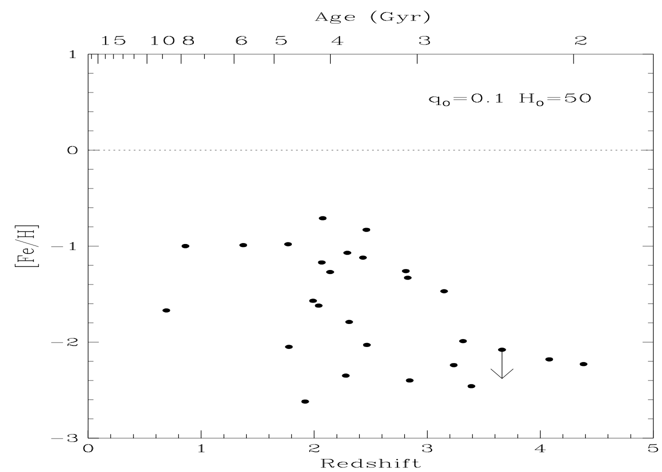

Figure 1: Metallicity distribution of damped Lyα absorbers.

higher metallicity at just slightly lower redshifts. This indicates an epoch of rapid star formation at $z \sim 3$. The effect is likely to be real: if DLA systems at $z > 3$ have [Fe/H] that is uniformly distributed between -1 and -2.5 (i.e.,, similar to the distribution at $2 < z < 3$), then the *posterior* probability for all six of the highest redshift systems to have [Fe/H]≤ -2 by chance is 1.4×10^{-3}.

Coincidentally, the metallicities of DLA systems at $z > 3$, [Fe/H]$= -2$ to -2.5, is identical (within the uncertainties) to those found for the IGM clouds at similar redshifts, as inferred from the C IV absorption associated with Lyα forest clouds [6,7,8]. This coincidence suggests that the metals in DLA galaxies at $z > 3$ may simply reflect those in the IGM, however they were made (e.g., Pop III stars, ejected from protogalaxies); DLA galaxies did not start making their own stars (hence metals) until $z \sim 3$.

3 Discussion

The implications of the above result for the general question of galaxy formation and evolution depend on the nature of the DLA galaxies.

It was suggested [9] that DLA systems may represent the progenitors of disk galaxies. This is supported by the very recent finding [10] that the kinematics of DLA absorbers as inferred from the metal absorption line profiles appears to be dominated by rotation with large circular velocities (> 200 km s^{-1}). However, the mean metallicities of DLAs at $z > 1.6$ are significantly

below that of the Milky Way disk at the corresponding epoch [4,11]. The problem with the metallicity distribution may be lessened if DLAs represent a thick disk phase of galaxies [3] or if low surface brightness disk galaxies (which have substantially sub-solar metallicities) make up a significant fraction of DLA absorbers [12]. *If* the disk hypothesis for DLA absorbers is correct, we may have identified the epoch of initial star formation in disk galaxies.

Alternatively, DLAs may represent dwarf galaxies or the spheroidal component of massive galaxies; this conjecture stems from the similarity between the metallicity distribution of DLAs and those in halo globular clusters and local gas-rich dwarf galaxies [4]. In this case, however, one has to explain the kinematics of DLAs [10] by other means.

Acknowledgments

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